

METHOD AND APPARATUS FOR OPTICAL ELEMENT MANAGEMENT

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of optical communication systems, and more particularly to a method and apparatus for managing one or more optical elements.

5

BACKGROUND

Optical amplification systems are becoming increasingly complex. For example, the number of channels being amplified continues to increase as the spacing between adjacent wavelengths utilized decreases and new communication bands are implemented. Moreover, as the distance the optical signals traverse increases, the number of optical elements and spans of fiber in each optical link increases.

As the amplification systems increase in complexity, it becomes increasingly difficult to track and manage the specifics of how each element is provisioned and the operational characteristics of the elements.

OVERVIEW OF EXAMPLE EMBODIMENTS

5 The present invention recognizes a need for a method and apparatus operable to facilitate monitoring and/or management of the operation of one or more optical elements. Various implementations of the present invention reduce or eliminate at least some of the shortcomings of conventional element management approaches.

10 In one aspect of the invention, a method of managing one or more optical elements comprises storing in a memory, provisioning information describing at least one setting of an optical element and monitored information describing at least one operational characteristic of the optical element. At least a portion of the monitored  
15 information is correlated with at least a portion of the provisioning information. The method further comprises maintaining in the memory, a correlation history comprising the provisioning information stored over time and the monitored information correlated to that  
20 provisioning information.

25 In another aspect of the invention, a method of managing one or more optical elements comprises accessing a memory comprising monitored information describing at least one operational characteristic of an optical element measured at a plurality of time periods. The  
30 memory further comprises provisioning information correlated with at least some of the monitored information. The provisioning information describes at least one setting of the optical element. The method also comprises retrieving provisioning information correlated with monitored information reflecting a desired operational characteristic of the optical

element. In addition, the method comprises applying at least a portion of the retrieved information to an application operable to monitor and/or modify the performance of the optical element based at least in part on the retrieved information.

In yet another aspect of the invention, a system operable to facilitate management of one or more optical elements comprises an element agent operable to receive provisioning information describing at least one setting of an optical element and monitoring information describing at least one operational characteristic of the optical element. At least a portion of the provisioning information is correlated with at least a portion of the monitored information. The system further comprises an element memory accessible to the element agent and operable to maintain a correlation history for the element, the correlation history comprising a plurality of correlated provisioning and monitored information measurements.

Depending on the specific features implemented, particular embodiments of the present invention may exhibit some, none, or all of the following technical advantages. For example, various embodiments of the invention facilitate maintaining a correlation history including provisioning information correlated with monitored information over a period of operation of an optical element, an optical link, or a plurality of optical links. The correlation history can facilitate various maintenance operations and/or efficiency enhancing functions with respect to the element's and/or link's operation.

For example, a graphical user interface (GUI) could display one or more sets of correlated provisioning information and monitored information to facilitate identification of trends in operation, to identify a malfunctioning component of the element, to facilitate optimization of operation, or various other utilities. As another example, the correlation history could facilitate "before and after" comparisons to assess the impact of a change in provisioning to the operation of the element and/or the link.

As still another example, the correlation history could facilitate identification of improper or inefficient provisioning settings in a particular element or link. As a related example, the correlation history could facilitate reversion provisioning. For example, the correlation history could store a set of provisioning information, which is known based, for example, on past experience to yield desired results. By indexing the correlation history using a portion of the provisioning information and one or more desired operational

characteristics, the remaining provisioning information associated with the desired operating characteristics can be recalled and applied to the element and/or the link.

5        These are just a few examples of advantageous uses  
of a correlation history in an optical amplification  
system. Various other uses of this information fall  
within the spirit and scope of this invention. Other  
technical advantages are readily apparent to one of skill  
in the art from the attached figures, description, and  
10        claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and for further features and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a block diagram showing an exemplary optical communication system constructed according to the teachings of the present invention;

FIGURE 2 is a block diagram showing one example of an amplification span constructed according to the teachings of the present invention;

FIGURE 3 is a block diagram of one example of a correlation history associated with a particular optical element constructed according to the teachings of the present invention;

FIGURE 4 is a block diagram of a link management system constructed according to the teachings of the present invention;

FIGURE 5 is a block diagram showing one example of a multiple link management system constructed according to the teachings of the present invention; and

FIGURE 6 is a flow chart illustrating one example of a method of managing one or more optical elements according to the teachings of the present invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

FIGURE 1 is a block diagram showing an exemplary optical communication system 10 operable to facilitate communication of one or more optical signals and to track and/or manage the operation of one or more optical elements in system 10. Optical amplifiers, optical add/drop multiplexers, cross connects, input terminals including optical transmitters, and output terminals including optical receivers provide just a few examples of optical elements that can be monitored and/or managed using system 10.

In this example, system 10 includes an input terminal 11. In the illustrated embodiment, input terminal 11 includes a transmitter bank 12 operable to generate a plurality of wavelength signals (or channels) 16a-16n. Each wavelength signal 16a-16n comprises a wavelength or range of wavelengths of light substantially different from wavelengths carried by other signals 16.

Transmitter bank 12 may include, for example, one or more optical transmitters operable to generate alone or in combination a plurality of wavelength signals 16. In one embodiment, each one of the plurality of transmitters is operable to generate one optical signal having at least one wavelength that is distinct from wavelengths generated by other transmitters 12. Alternatively, a single transmitter 12 operable to generate a plurality of wavelength signals could be implemented.

In the illustrated embodiment, input terminal 11 also includes a combiner 14 operable to receive multiple signal wavelengths 16a-16n and to combine those signal wavelengths into a single multiple wavelength signal 16. As one particular example, combiner 14 could comprise a



wavelength division multiplexer (WDM). The term wavelength division multiplexer as used herein may include wavelength division multiplexers or dense wavelength division multiplexers.

5 In this particular example, input terminal 11 further includes a booster amplifier 18 operable to receive and amplify wavelengths of signal 16a in preparation for communication over a communication medium 20. Although this example illustrates input terminal 11  
10 as including each of transmitter bank 12, combiner 14, and booster amplifier 18, one or more of those elements could reside externally to input terminal 11.

System 10 communicates optical signal 16 over an optical communication medium 20. Communication medium 20  
15 can comprise a plurality of spans 20a-20n of fiber, each separated by an optical element. As used in this document, the term "span" refers to an optical medium coupled to one or more optical elements. As particular examples, fiber spans 20 could comprise standard single  
20 mode fiber (SMF), dispersion-shifted fiber (DSF), non-zero dispersion-shifted fiber (NZDSF), or other fiber type or combinations of fiber types.

Two or more spans of medium 20 can collectively form an optical link. As used herein, the term "optical link"  
25 refers to a plurality of optical spans coupled to one or more optical elements. In the illustrated example, system 10 includes one link 25. System 10 could alternatively include any number of additional links.

In this example, system 10 also includes one or more  
30 in-line amplifiers 22a-22m. In-line amplifiers 22 reside between fiber spans 20 and operate to amplify signal 16 as it traverses fiber 20.

In this example, system 10 includes one or more add/drop multiplexers, switches, and/or routers 15 coupled to communication medium 20 and operable to direct signals to and from optical link 25 for combination with signals to and from other optical links. Element 15 may be coupled to an amplifier or may itself be capable of amplifying optical signals received.

System 10 can also include an output terminal 13 operable to receive signals from communication link 20 and to facilitate, for example, conversion of the optical signals to an electrical format. In this example, output terminal 13 includes a preamplifier 24 operable to receive signal 16 from a final fiber span 20n and to amplify signal 16 prior to passing that signal to a separator 26. Separator 26 may comprise, for example, a wavelength division demultiplexer (WDM). Separator 26 operates to separate individual wavelength signals 16a-16n from multiple wavelength signal 16. Separator 26 can communicate individual signal wavelengths or ranges of wavelengths 16a-16n to a bank of receivers 28 and/or other optical communication paths. Although this example illustrates output terminal 13 as including each of preamplifier 24, separator 26, and receivers 28, one or more of those elements could reside externally to output terminal 13.

Amplifiers within system 10 could each comprise, for example, a rare earth doped amplifier such as an erbium doped or thulium doped amplifier, a Raman amplifier, a semiconductor amplifier, or a hybrid or combination of these or other amplifier types.

At least one optical element in system 10 comprises or communicates with a management system 30 operable to

track and/or manage the performance of that element or of the optical link containing that element. Management system 30 operates to store provisioning information describing at least one setting of the element and to store monitored information describing at least one operational characteristic of the element. Management system 30 correlates at least some of the provisioning information with at least some of the monitored information and maintains a correlation history useful in a variety of applications.

FIGURE 2 is a block diagram showing one example of an amplification span 100 including an optical element 110 and an element manager 130 operable to track and/or manage the performance of element 110. In this particular example, element 110 comprises an input terminal including a plurality of optical transmitters and a booster amplifier. Although this example describes implementing element manager in combination with an input terminal, element manager 130 could alternatively be used to track and/or manage any other type of optical element in system 10, such as an in-line or other type of amplifier, an output terminal, an add/drop multiplexer, a cross connect, or a router, to name a few.

The booster amplifier of element 110 may comprise any type of amplifier including, for example, a rare-earth doped amplifier, a distributed Raman amplifier, a discrete Raman amplifier, a semiconductor amplifier, or a combination of these or other types of amplifiers. Element 110 couples to optical span 120a, which might comprise, for example, a span of standard single mode fiber, dispersion-shifted fiber, non-zero

dispersion-shifted fiber, or other fiber type or combinations of fiber types.

Element manager 130 includes an element agent 132 operable to receive provisioning information 140 and monitoring information 142. Provisioning information 140 comprises information describing at least one setting of element 110. For example, provisioning information 140 could comprise information relating to the gain of the preamplifier in element 110, a laser drive current associated with one or more of the transmitters or the preamplifier in element 110, a pre-emphasis level associated with element 110, or a number of channels being processed by element 110, to name a few. Other optical elements may store these or various other items of provisioning information, depending on the particular application of the optical element.

Monitored information 142 comprises information describing at least one operational characteristic of element 110. Monitored information 142 can be obtained at various locations along amplification span 100. For example, monitored information 142 may be collected from an input to element 110 or from an output of element 110. Examples of monitored information 142 include input power, output power, mid-stage power, gain tilt, signal-to-noise ratio, back reflected power, total transmitted power, per channel transmitted power, total received power, or per channel received power, pump laser power, pump laser drive current, thermal electrical cooler settings, thermal electrical cooler drive currents, to name a few. Of course, the particular monitored information collected can vary depending on the function of the element being monitored. Moreover, other

or additional operational characteristics could be monitored without departing from the scope of the invention.

5 In one particular embodiment, element agent 132 operates to query element 110 to obtain provisioning information 140 and/or monitored information 142. Rather than recording provisioning information 140 and/or monitored information 142 only when provisioning characteristics are changed, element agent 132 can  
10 periodically, on a random basis, or on command query element 110 to retrieve provisioning information 140 and/or monitored information 142.

Regardless of how or when element agent 132 receives provisioning information 140 and monitored information  
15 142, element agent 132 stores the information received in a memory 134. Memory 134 may comprise, for example, any hardware, firmware, software, or combination thereof operable to store and facilitate retrieval of information. Memory 134 can comprise any of a variety of  
20 data structures, arrangements, or compilations operable to store and facilitate retrieval of various information. This may include, for example, the use of a dynamic random access memory (DRAM), a static random access memory (SRAM), or any other suitable volatile or  
25 non-volatile storage and retrieval device or a combination of devices. Although, in this embodiment, memory 134 is shown as residing within element manager 130, all or a portion of memory 134 could reside remotely from and accessible to element agent 132.

30 In the illustrated embodiment, memory 134 includes a correlation history 136. Correlation history 136 may comprise, for example, a memory operable to store

provisioning information 140 and monitored information 142, where at least a portion of monitored information 142 is correlated with at least a portion of provisioning information 140. Correlation history 136 can include a plurality of sets of correlated provisioning information 140 and monitored information 142 stored over a period of time of operation of element 110.

Memory 134 is accessible to one or more applications 150 operable to monitor, display, report on, analyze, and/or modify the performance of element 110 based at least in part on information retrieved from memory 134.

In operation, element agent 132 receives provisioning information 140 and monitored information 142 correlated with at least a portion of provisioning information 140. In a particular embodiment, element agent 132 may query element 110 to retrieve this information. Element agent 132 may receive provisioning information 140 and correlated monitored information 142 at various times during operation of element 110.

Element agent 132 stores provisioning information 140 and correlated monitored information 142 in memory 134. In a particular embodiment, element agent 132 stores provisioning information 140 and correlated monitored information 142 associated with a particular time period in a record stored in correlation history 136. Over time, element agent 132 may store a plurality of records containing provisioning information 140 and correlated monitored information 142 associated with particular time periods. In a particular embodiment, these records can collectively form correlation history 136.

One or more applications 150 access information in memory 134 to track and/or manage the performance of element 110. As one particular example, application 150 may comprise a graphical user interface (GUI) operable to display one or more sets of correlated provisioning information 140 and monitored information 142. This may facilitate, for example, inspection of provisioned and operational characteristics of element 110 to identify trends in operation, to identify a malfunctioning component of element 110, to facilitate optimization of operation, or various other utilities.

As another example, application 150 could comprise a benchmarking application operable to facilitate "before and after" comparisons to assess the impact of a change in provisioning to the operation of element 110.

As still another example, application 150 could comprise a trouble shooting application operable to identify improper or inefficient provisioning settings in element 110. For example, trouble shooting application 150 could index correlation history 136 using monitored information representing desired operational characteristics to identify provisioning information previously correlated with those characteristics. This provisioning information could represent a provisioning state known to produce desirable operational characteristics. Application 150 can then compare the retrieved provisioning information 140 with the current element settings to facilitate identification of problems with and/or modification of the provisioning of element 110 so that its operation can more closely approximate the desired state of operation.

As a related example, application 150 could facilitate reversion provisioning. For example, correlation history 136 may store a set of provisioning information 140, which is known based, for example, on past experience to yield desired results. By indexing correlation history 136 using a portion of the provisioning information and one or more desired operational characteristics, the remaining provisioning information associated with the desired operating characteristics can be recalled.

As a particular example, one set of provisioning information 140 and monitored information 142 may identify pump power levels, pre-emphasis levels, and/or amplifier gain levels associated with a particular number of channels and particular operational characteristics. As the number of channels processed by element 110 changes over time, provisioning information 140 associated with the element may also change. When the number of channels returns to its original state, a reversion provisioning application 150 can facilitate automatically reverting to the set of provisioning information previously used by element 110 when dealing with that particular number of channels. This can eliminate guesswork and inefficiency associated with trying to recreate that set of provisioning information based on a trial and error approach. By, for example, searching correlation history 136 for provisioning information 140 containing a desired number of channels, and possibly correlated with a desired output characteristic, reversion provisioning application 150 can apply all or a part of the retrieved provisioning



information 140 to revert element 110 to previously approved element settings.

These are just a few examples of advantageous uses of correlation history 136 in system 100. Various other  
5 uses of this information fall within the spirit and scope of this invention.

FIGURE 3 is a block diagram of one example of a correlation history 236 associated with a particular optical element, for example, optical element 110  
10 described with respect to FIGURE 2. In this example, correlation history 236 includes a plurality of records 210a-210n. Each record includes provisioning information 240 and monitored information 242 associated with element 110 at a particular time 250.

Provisioning information 250 may include, for  
15 example, information regarding channel pre-emphasis used in element 110 as well as and the number of channels processed by element 110. Other provisioning information could be stored without departing from the scope of the  
20 invention. Monitored information 242 could include, for example, input power, mid-stage power, output power, gain tilt, optical-signal-to-noise-ratio, back reflected power, or any other operational characteristics associated with element 110.

In a particular embodiment, any individual piece of  
25 provisioning information 240 can be used as an index to retrieve any piece of monitored information 242 residing in the same record. Likewise, items of monitored information 242 can be used as an index to retrieve any  
30 item of provisioning information 240 from the same record 210. In addition, any piece of provisioning or monitored information could be used to access all or a portion of

any other correlated information. Other arrangements and correlation schemes could be used without departing from the scope of the invention. The above-described correlation is intended as just one example.

5           FIGURE 4 is a block diagram of a link management system 300. Link management system 300 includes an optical link 320 comprising a plurality of spans 320a-320n. Each optical span comprises an optical fiber coupled to one or more optical elements 310. Each  
10       element in system 300 has associated with it a local element manager 330. Local element managers 330 are similar in structure and function to element manager 130 described with respect to FIGURE 2. Each local element manager 330 includes an element agent 332 operable to  
15       receive provisioning information 340 and monitored information 342 from its associated element 310. Element agents 332 store provisioning information 340 and monitored information 342 in their associated memories 334.

20           As in the embodiment shown in FIGURE 2, memories 334 may store correlation histories 336, which include provisioning information 340 correlated to monitored information 342. One or more element applications 350 may access memories 334 to track and/or modify  
25       performance of individual elements 310 or combinations of elements 310.

30           In the illustrated embodiment, system 300 includes a link manager 360 operable to track and/or modify performance of one or more elements 310 and/or the entire optical link 320. In this example, link manager 360 includes a manager agent 362 operable to receive provisioning and monitored information from each of

elements 310. Manager agent 362 may receive this information, for example, through each element agent 332 querying elements 310, or may obtain information already queried or otherwise received from elements 310 and stored in element memories 334. Link manager 360 also includes one or more memories 364. Memory 364 stores information associated with each element 310 in optical link 320.

Link manager 360 may also receive information from adaptation module 370. Adaptation module 370 comprises hardware, software, and/or firmware operable to facilitate retrieval of provisioning and/or monitored information of various manufacturers' equipment. For example, equipment interfacing with adaptation module 370 may provide provisioning and/or monitored information in a format other than the format typically used by link manager 360. Adaptation module 370 operates to reformat the information received so that it can be assimilated and/or correlated with other information associated with optical link 320.

Link manager 360 may further include one or more applications 365 operable to track and/or manage operation of elements 310 and/or optical link 320 based at least in part on provisioning information and monitored information associated with those elements. Application 365 may obtain such information, for example, from records residing in manager memory 364. Application 365 may provide some or all of the functions of application 150 described with respect to FIGURE 2. In addition, application 365 may facilitate tracking and/or managing the operation of optical link 320.

For example, application 365 may facilitate identifying a malfunctioning component in one or more elements 310 by examining the operation of optical link 320. As a particular example, a pump driving one of an  
5 element including an amplifier may be weakening. Application 365 may compare various characteristics associated with elements in optical link 320 to identify the weakening amplifier pump. Application 365 may, for example, compare input powers to each amplifier and pump powers driving each amplifier to determine the location  
10 of a weakening pump.

In one case, application 365 may determine that a particular element 310b is receiving an appropriate power level input signal, but exhibiting a high drive current  
15 to its laser pump. This indicates that the driving source associated with element 310b is likely weakening. In another case, application 365 may determine that although element 310b has an abnormally high pump power, the input signal to element 310b is abnormally low. This  
20 could indicate, for example, a malfunction in the previous amplifier 310a in that span, or a fault in optical span 320b between elements 310a and 310b. System 300 facilitates pinpointing the location of a malfunction in an optical link by facilitate simultaneous analysis of  
25 characteristics associated with a number of elements 310 along optical link 320.

In this example, link manager 360 includes an interface 380, which facilitates an external application  
30 390 accessing and retrieving information from manager memory 364. External application 390 may comprise a module remote from optical link 320, which is operable to access provisioning and monitored information associated

with link 320 and to facilitate tracking and/or management of elements 310 and/or optical link 320. Interface 380 could provide security features to protect correlation histories 364 from unauthorized access by external entities.

In this particular example's operation, link 320 receives optical signals at an element 310a comprising an amplifier, which amplifies the optical signals and communicates them toward the next element 310. Element agents 332 associated with each element 310 may periodically, on a random basis, or on command receive or retrieve provisioning and monitored information from one or more elements 310. Element agents 332 store the provisioning and correlated monitored information in correlation histories 336 of memories 334. Manager agent 362 on demand, on a periodic basis, or on a random basis, accesses and retrieves provisioning and correlated monitored information associated with each element 310 and stores that information in manager memory 364. Manager applications 365 and/or external applications 390 track and/or modify the operation of elements 310 and/or optical links 320 based at least in part on provisioning and monitored information associated with those amplifiers.

FIGURE 5 is a block diagram showing one example of a multiple link management system 400. Multiple link management system 400 includes a system manager 460 operable to track and/or manage one or more optical links in system 400. System manager 460 is similar in structure and function to link manager 360 shown in FIGURE 4, and has capabilities of managing numerous optical links 420a-420n.

System manager comprises a manager agent 462 operable to receive provisioning and monitored information from numerous elements in one or more optical links 420a-420n. Manager agent 462 can receive this information, for example, through each element agent 432 querying elements 410, or may obtain information already queried or otherwise received from elements 410 and stored in element memories 434. System manager 460 also includes one or more memories 464a-464n. Memories 464a-464n could be physically separate storage devices, or could comprise logically partitioned regions of one or more common memory devices. Each memory 464 stores information associated with each element 410 in its associated optical link 420.

System manager 460 may also receive information from adaptation module 470. Adaptation module 470 comprises hardware, software, and/or firmware operable to facilitate retrieval of provisioning and/or monitored information of various manufacturers' equipment. For example, equipment interfacing with adaptation module 470 may provide provisioning and/or monitored information in a format other than the format typically used by link manager 460. Adaptation module 470 operates to reformat the information received so that it can be assimilated and/or correlated with other information associated with optical link 420.

Link manager 460 may further include one or more element applications 465a-465n operable to track and/or manage operation of elements 410 and/or optical links 420 based at least in part on provisioning information and monitored information associated with those elements and/or links. Applications 465 may provide some or all

of the functions of application 150 described with respect to FIGURE 2. In addition, application 465 may facilitate tracking and/or managing the operation of optical links 420a-420n individually, or in combination with one another.

FIGURE 6 is a flow chart illustrating one example of a method 500 of managing one or more optical elements. To provide one particular example, method 500 will be described with primarily with respect to management system 100 shown in FIGURE 2. Other management systems managing different types of optical elements could implement method 500 without departing from the scope of the invention.

In this example, method 500 begins at step 510 where system 100 stores provisioning information 140 in element memory 134. System 100 can obtain provisioning information 140, for example, by using query module 133 to query element 110 on command, periodically, or on a random basis to obtain provision information 140. In a similar manner, system 100 stores monitored information 142 in memory 134. Element agent 132 could, for example, implement query module 133 to retrieve monitored information 142.

Element agent 132 maintains a correlation history 136 at step 530. Correlation history 136 comprises a plurality of correlated values of provisioning information 140 and monitored information 142. Correlation history 136 provides a historical view of the manner in which monitored information 142 varies as provisioning information 140 changes. In addition, correlation history 136 can show the way monitored

information 142 can change over time even though provisioning information 140 remains constant.

In this example, element agent 132 accesses memory 134 at step 540 to retrieve correlated provisioning and monitored information. Element agent 132 applies at least a portion of the retrieved correlated information to application 150 at step 550. As particular non-limiting examples, application 150 can operate to display correlated information to users, or may analyze this information to facilitate modifying the operation of element 110. For example, application 150 may retrieve provisioning information from correlation history 136 by indexing correlation history 136 with a known value of monitored information 142 corresponding to a desired state of operation. Application 150 can then compare the retrieved provisioning information with provisioning information currently associated with element 110 to determine changes that need to be made in the provisioning of element 110 to result in the desired state of operation.

As another example, application 150 could perform reversion provisioning. As one example of reversion provisioning, application 150 could index correlation history 136 using one portion of provisioning information 140 to obtain a full set of provisioning information associated with that portion and possibly also associated with a desired state of operation.

Although this example has been described with respect to managing a single element 110, method 500 can equally apply to management of multiple elements in a single optical link, or to managing multiple optical links. Systems shown in FIGURES 4 and 5 provide two



non-limiting examples of systems that could implement method 500.

Although the present invention has been described in several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformations, and modifications as fall within the spirit and scope of the appended claims.

5

10

11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
2158  
2159  
2160  
2161  
2162  
2163  
2164  
2165  
2166  
2167  
2168  
2169  
2170  
2171  
2172  
2173  
2174  
2175  
2176  
2177  
2178  
2179  
2180  
2181  
2182  
2183  
2184  
2185  
2186  
2187  
2188  
2189  
2190  
2191  
2192  
2193  
2